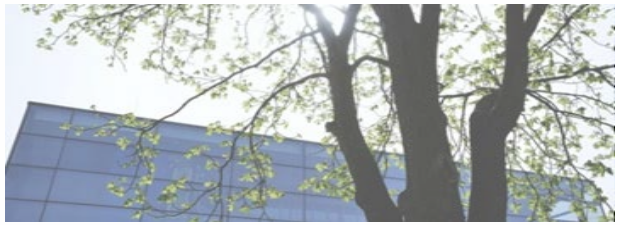



Global Energy Scenarios and Innovation

Institute for Advanced Sustainability Studies
IASS in Potsdam

Prof. C. C. Chan, Senior Fellow
Fellow, Royal Academy of Engineering, U.K.
Academician, Chinese Academy of Engineering

Content

- **WEC Global Energy Scenarios : Jazz and Symphony**
- **Innovation of Wind Power – pre-processed, without big blade;**

  Projects in China and U.S.A,
- **Relationship between Energy and Information, not only the relation in quantity but also the nature.**

WORLD ENERGY COUNCIL
CONSEIL MONDIAL DE L'ÉNERGIE

Project Partner:
Paul Scherrer Institute

World Energy Scenarios

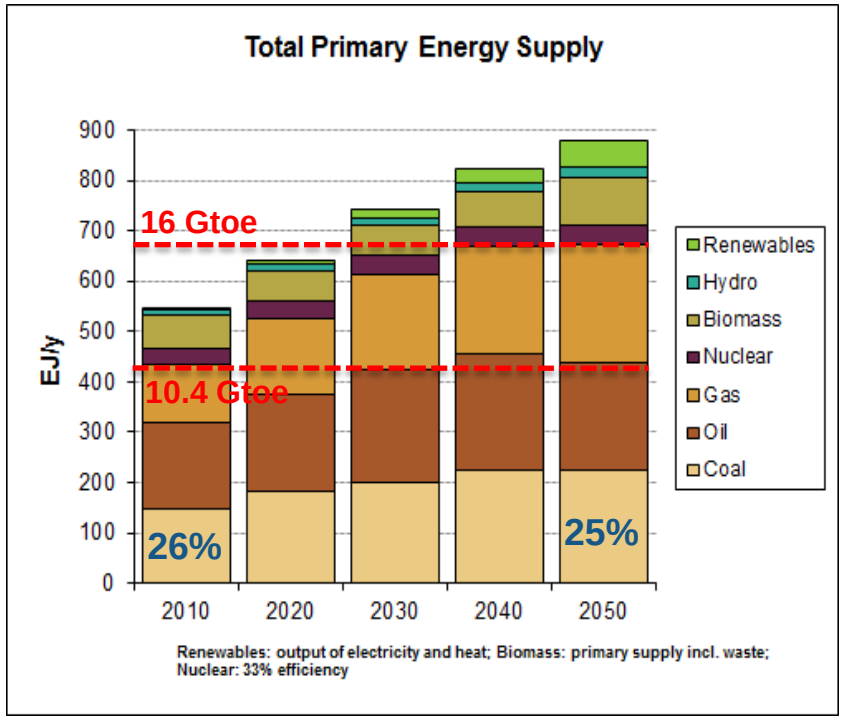
WEC Scenarios
Deriving the scenario stories

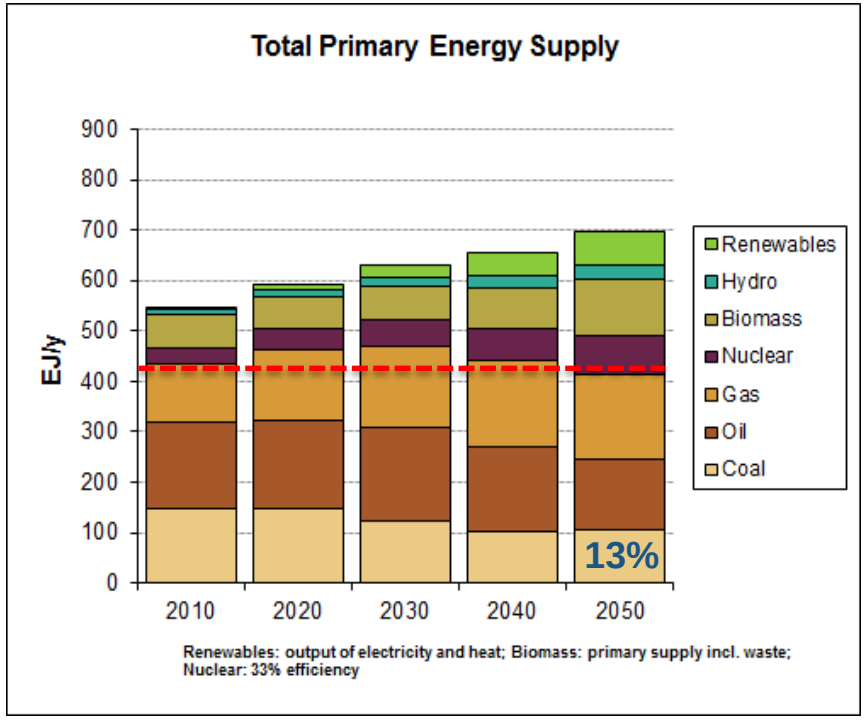
Two Scenarios stories, exploratory, different and equally probable rather than good and bad

Jazz:
Market & trade based, consumer driven, decentralized decision making, focussed on access and affordability. achieving growth through low cost energy. Governments facilitate GHG actions.

Symphony:
Government led, "orchestrated", voter driven, focussed on environmental goals and energy security, national and regional measures to increase share of renewables in energy mix. Binding international agreement on GHG emissions.

Global total primary energy supply





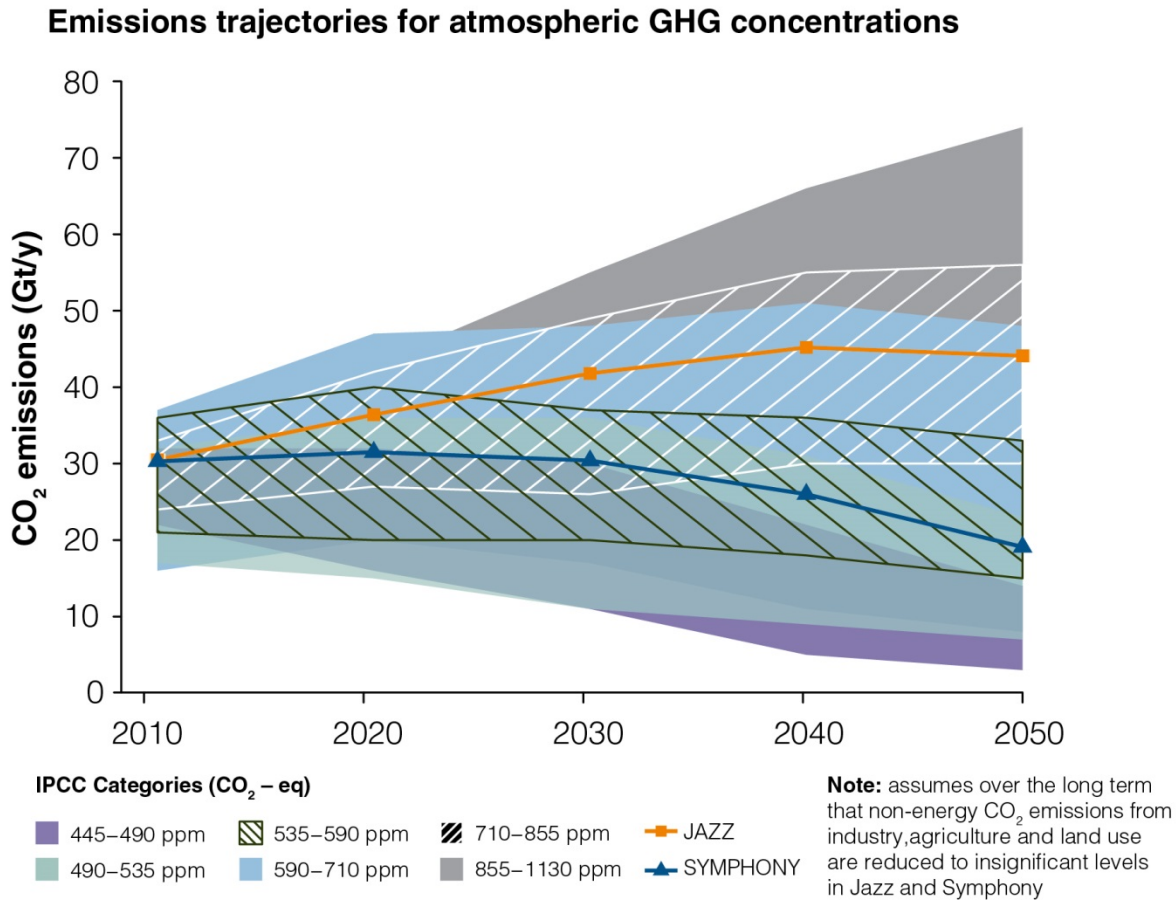
Jazz — **fossil fuels: +55%/- 5%** — **Symphony**

- oil: +/- 15%
- natural gas: +100%/+50%
- coal: +/- 40%

Upstream liberalized;
technology development,
supply surge/more producers
Coal remains dominant in some regions

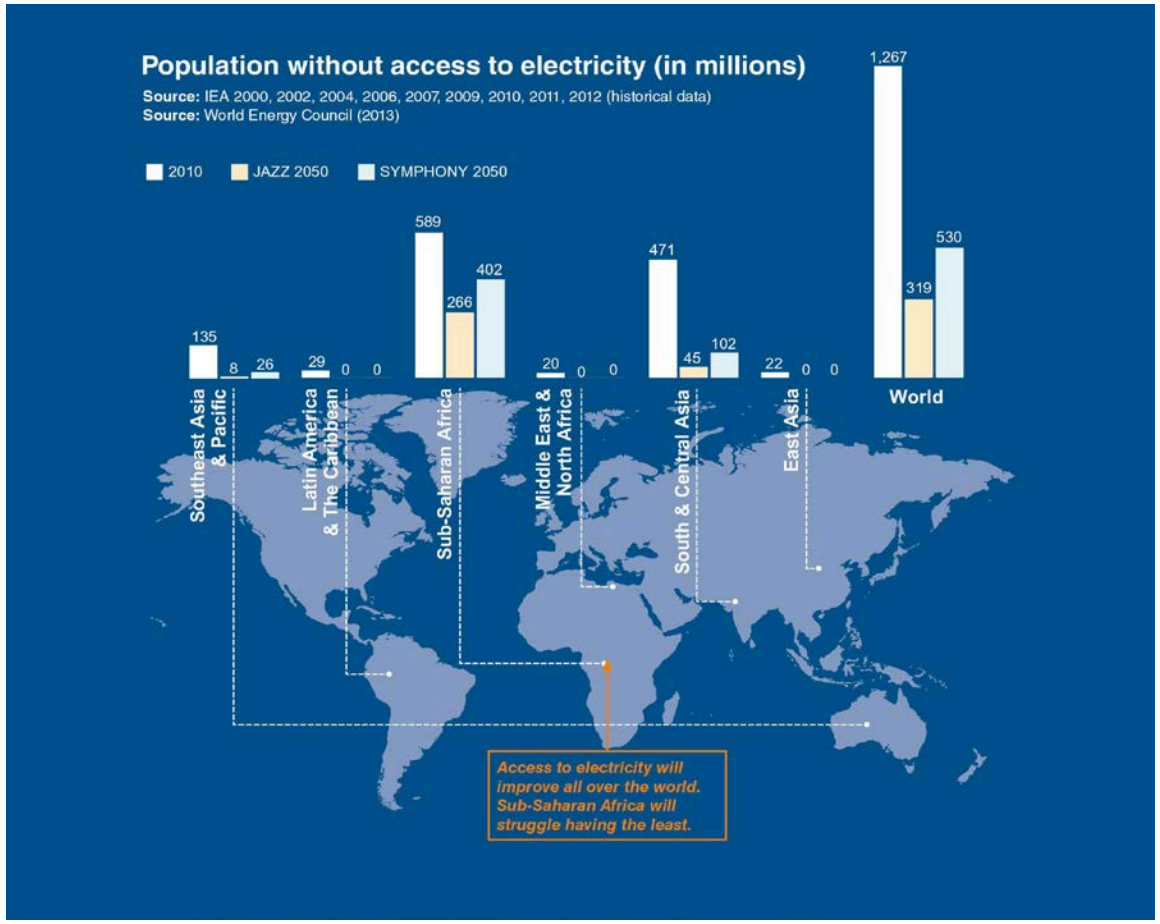
Tighter supply (lower E&P)
Higher infrastructure costs
Energy security drives reduced fossil use

Resulting CO_2 emissions



The global economy will be challenged to meet the 450 ppm target without enormous economic costs

Access to electricity in 2050



JAZZ:

- 310 million without access in 2050

SYMPHONY:

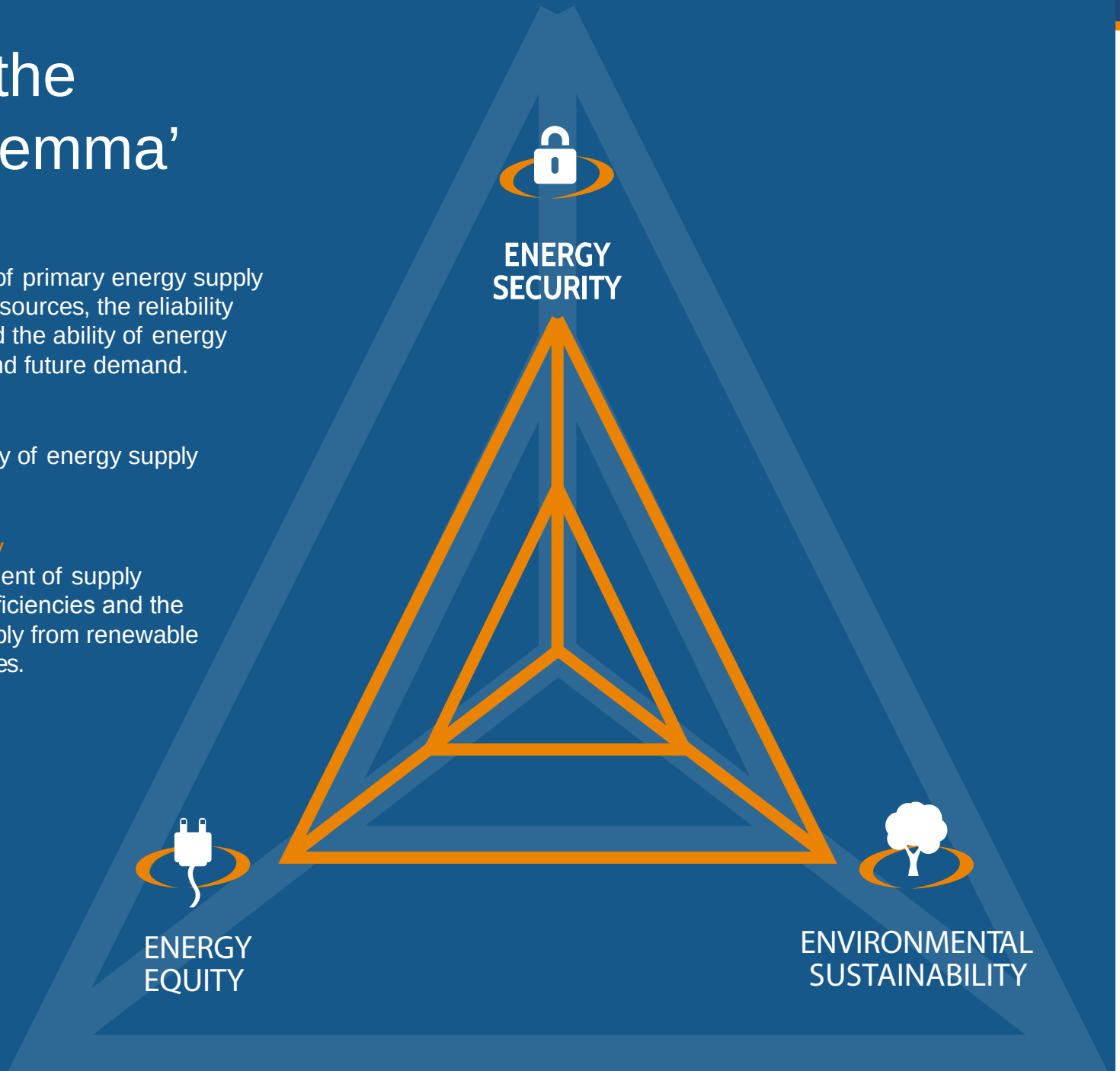
- 530 million without access in 2050

Balancing the ‘Energy Trilemma’

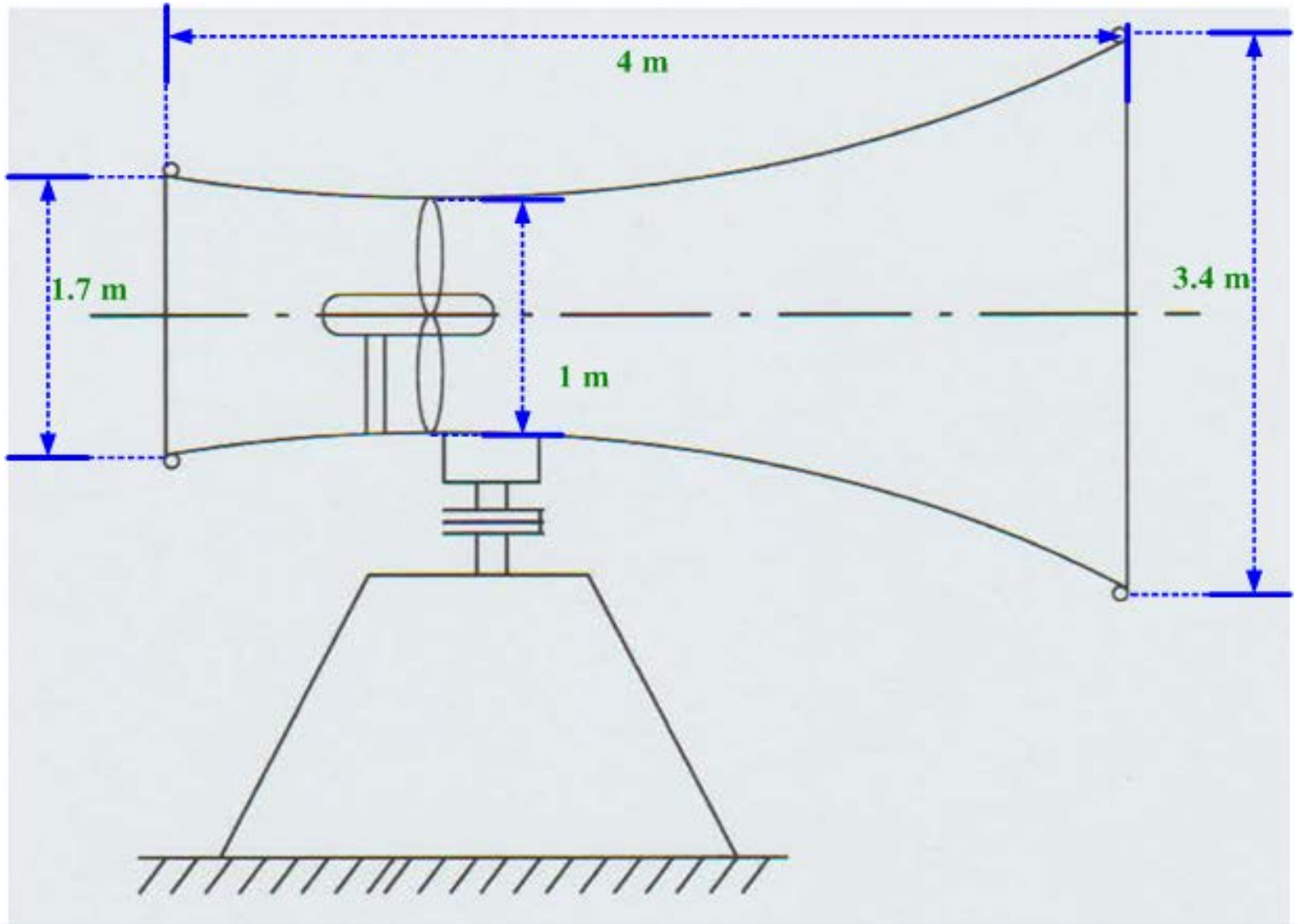
Energy Security
The effective management of primary energy supply from domestic and external sources, the reliability of energy infrastructure, and the ability of energy providers to meet current and future demand.

Energy Equity
Accessibility and affordability of energy supply across the population.

Environmental Sustainability
Encompasses the achievement of supply and demand side energy efficiencies and the development of energy supply from renewable and other low-carbon sources.



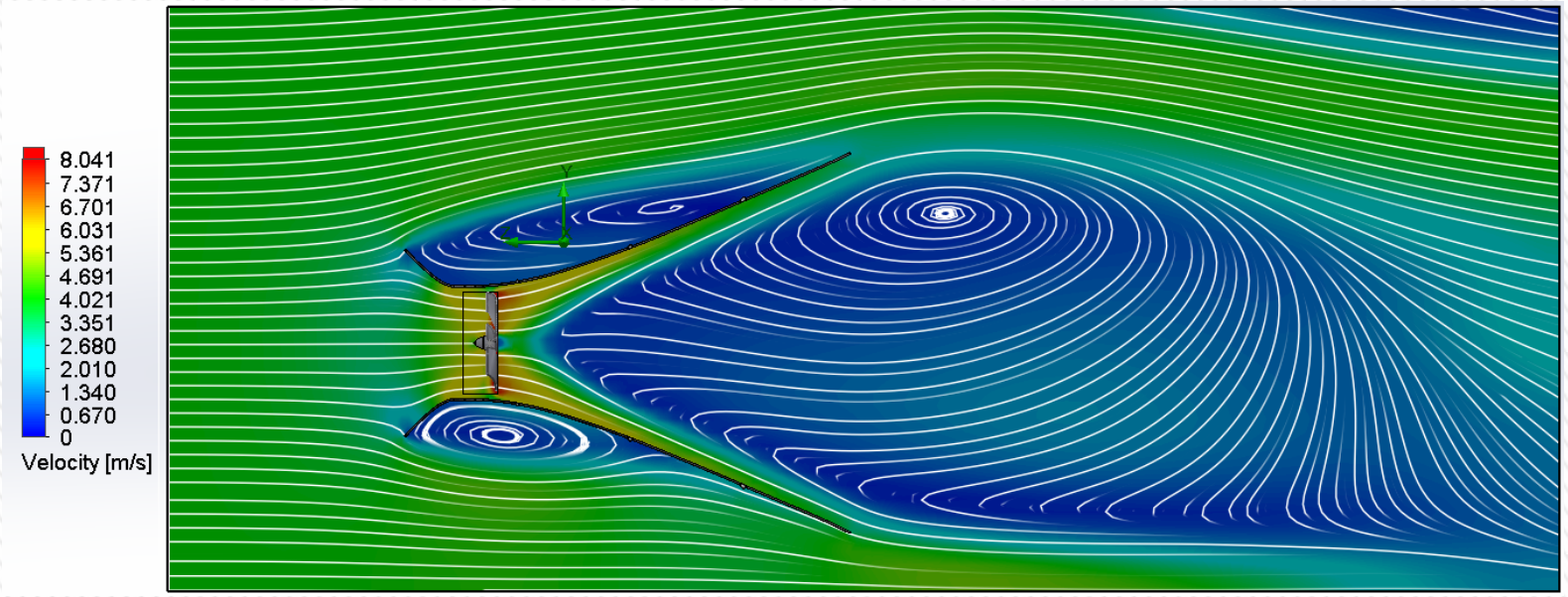
Innovation in Wind Power



(1) ***Conquer Sandstorm*** / 征服沙尘暴； (2) ***Low altitude wind tunnel power generation***/低空风洞发电； (3) ***Governance from the origin*** / 从源头治理； (4) ***Turning disaster into welfare*** /变灾害为福利；(5) ***High economic and society benefits***/巨大经济和社会效益

A Breach to the Dust Storm Problem
解決方案

- Dust storm formation requires an unstable atmosphere and accumulation of energy in desert.
  從形成機制可知, 沙塵暴的出現必需要有能量累積。
- Reducing the accumulation of excessive energy in desert → reducing the chance of dust storm formation.
  因此, 只要減少多餘能量累積, 就能減低沙塵暴出現的機會。
- Inducing the accumulated energy for electricity generation
  → use the electricity for ecology,
  → A self-healing mechanism for desert.
  誘導沙漠地表能量沿水平方向至沙漠邊緣進行發電, 就能減少能量的累積及熱氣流上升的機會, 消除沙塵暴的温床。再利用所得的電能保护生态, 使得沙漠利用自身的能量進行自我修復。



» **A trumpet-like wind duct design:**

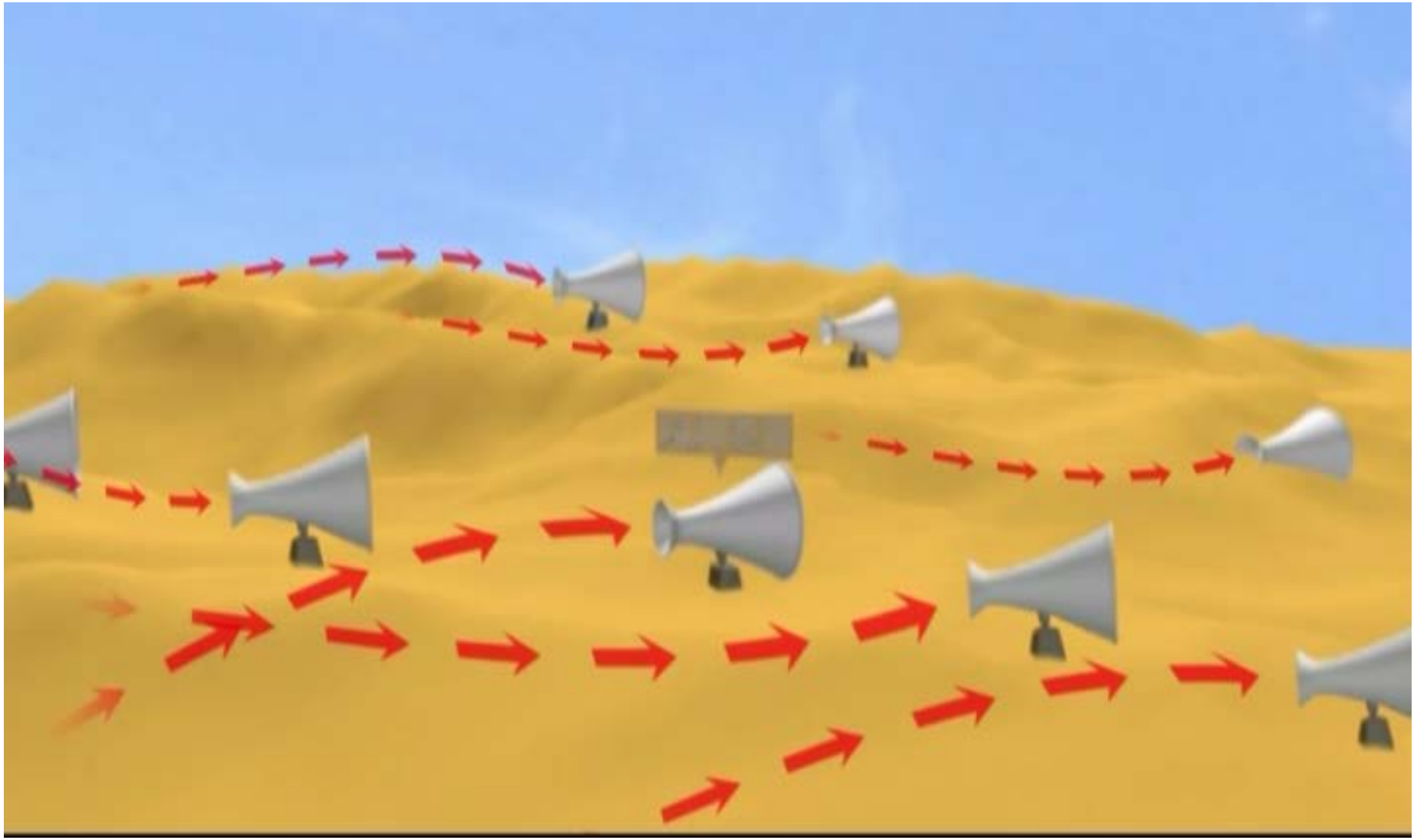
- **Slightly narrowed part in the middle → Acceleration of air from inlet.**
- **The outlet is much more widened → Allows a smooth circulation of air.**

風洞的設計為中間微微收窄的喇叭狀, 把空氣作行加速以作發電。排風口變寬, 以疏導空氣流出。

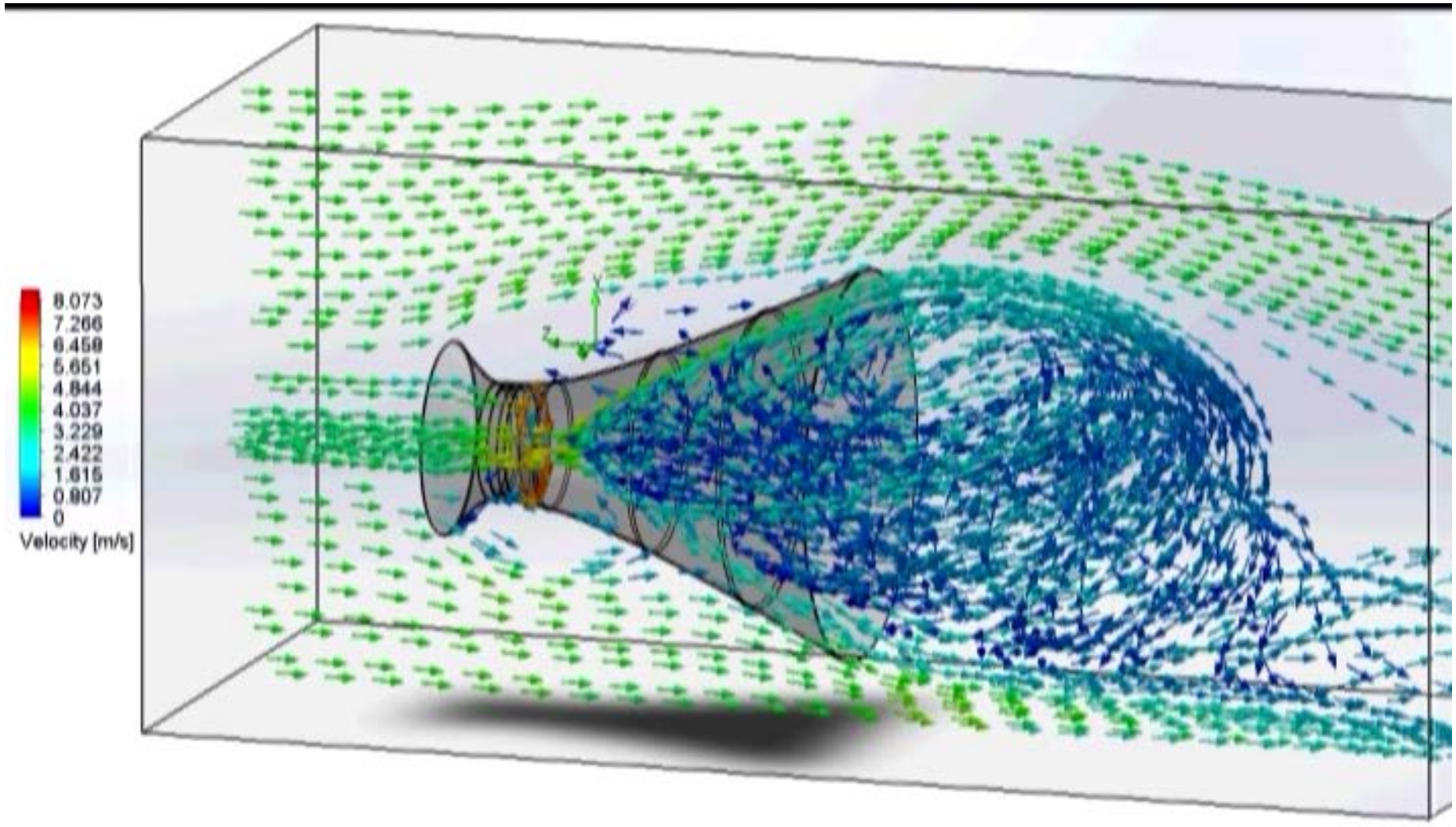
» **Simulation of the Ducted Wind Power Generator:**

- **Inlet is on the left side (Initial wind speed: 4 m/s, color Green).**
- **The air is accelerated in the middle part to 2 times of the initial speed (about 8 m/s, color Red Orange).**

上圖為風洞發電機的模擬圖。入風口在左側, 水平風速為4米每秒 (綠色); 而當空氣進入風道以後, 空氣加速至約每秒8米(橙紅色), 約2倍。



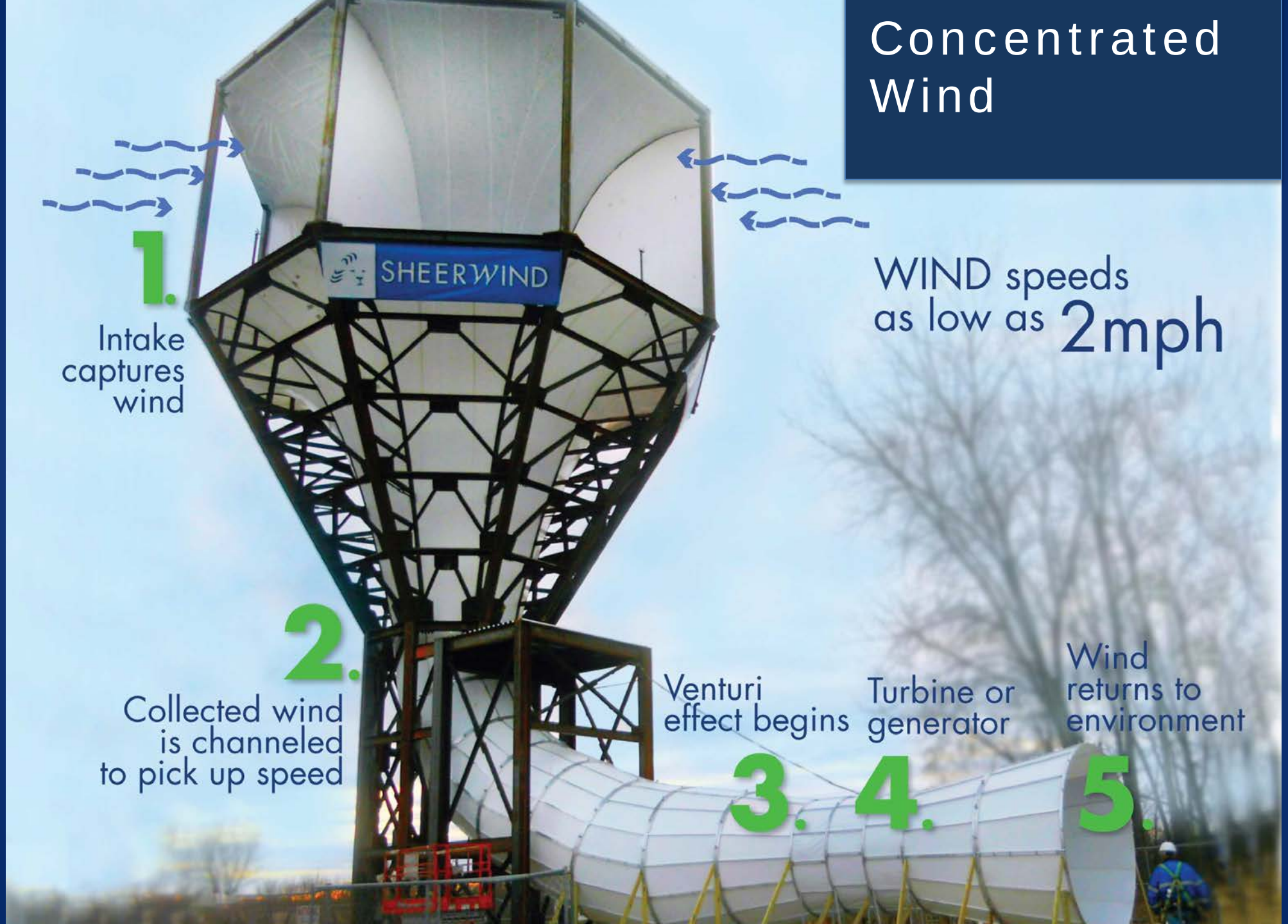
→ ***Inducing Sand Wind into Wind Tunnel***
诱导风沙进入风洞



→ ***Bernoulli Law Effect /伯努利定律效应***

→ ***Wind Power Generation /风力发电***

Concentrated Wind



INVELOX Solves Traditional Wind Power Issues

No Radar Interference
(INVELOX minimizes signature)

No Noise & Flickering
(INVELOX has no exposed blades

Less Land Use
(INVELOX uses a fraction)

Low Cut-in Wind Speed
(2 vs. 8.5 mph)

Improved Turbine Reliability
(INVELOX turbine & generator not exposed)

No Icing
(turbine blades not exposed)

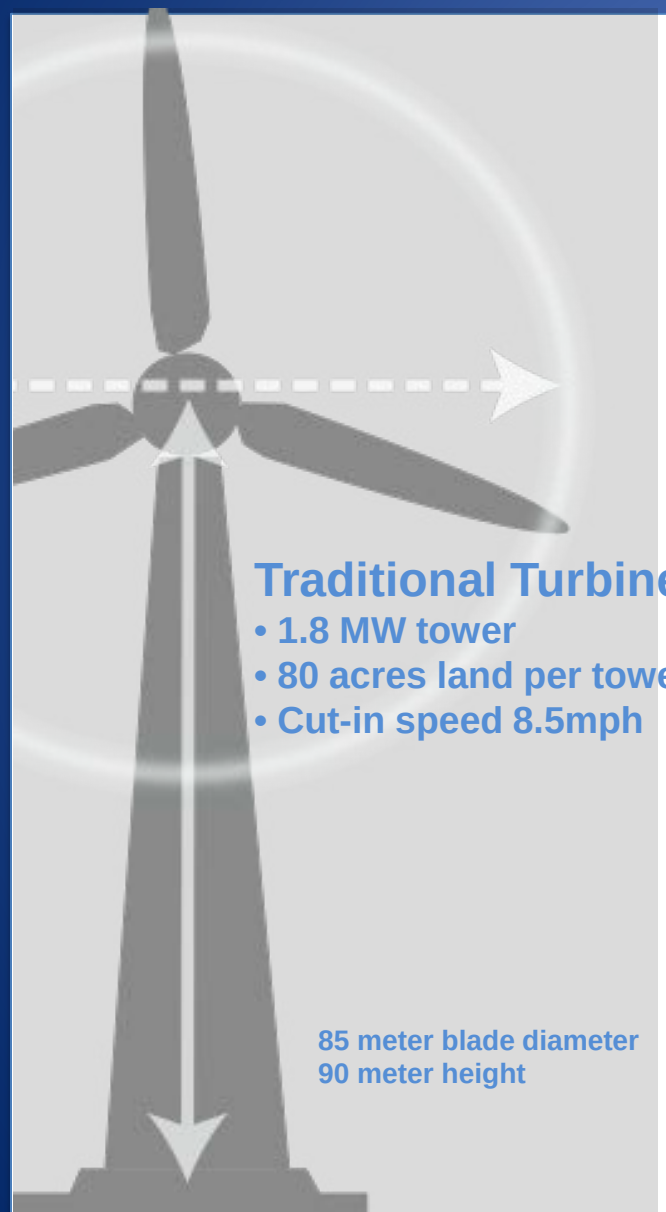
Reduced Distance from Grid
(INVELOX close to user)

Low Cost
(INVELOX has reduced building & O&M costs)

Improved Visual Impact

No Bird Strikes
(INVELOX has no rotating blades)

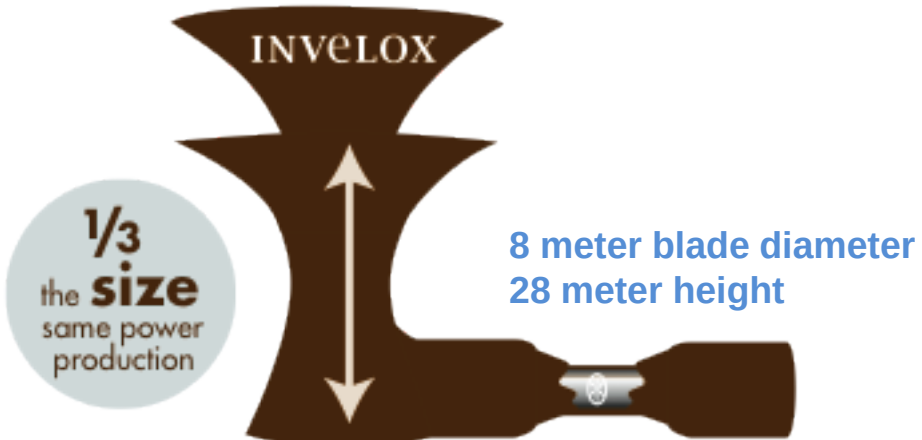
Patented INVELOX
Outperforms Traditional Wind Systems



Traditional Turbine
- 1.8 MW tower
- 80 acres land per tower
- Cut-in speed 8.5mph

85 meter blade diameter
90 meter height

INVELOX System
- 1.8 MW tower
- 10 acres land per tower
- Cut-in speed 2 mph



8 meter blade diameter
28 meter height

INVELOX For Wind Power Plants

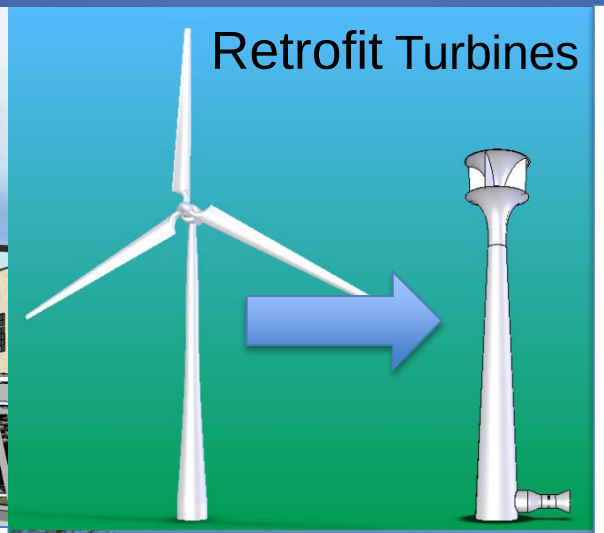
Financial Factor	Financial Benefit	% Savings(1)
Cost of Energy	¢1.4 / KWh	64%
Payback	5 Years	60% shorter
15-Year ROI	25% to 30%	300%
CAPEX	$750 per KW	43%
O&M	$3 per MWh	50%

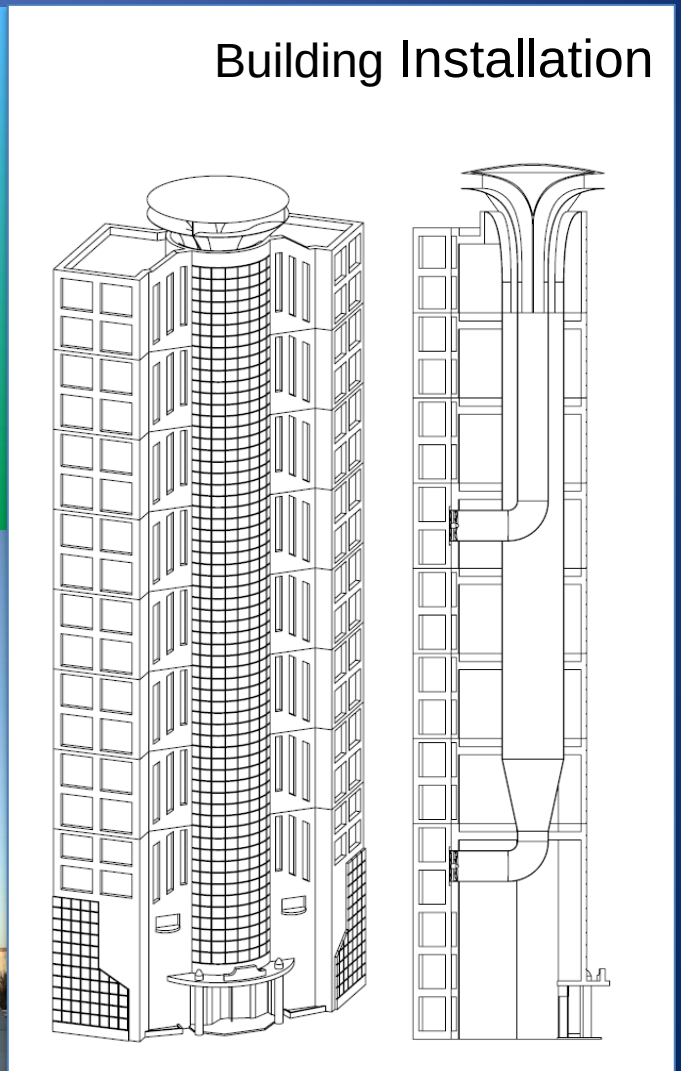
(1) Compared with Conventional Wind Energy

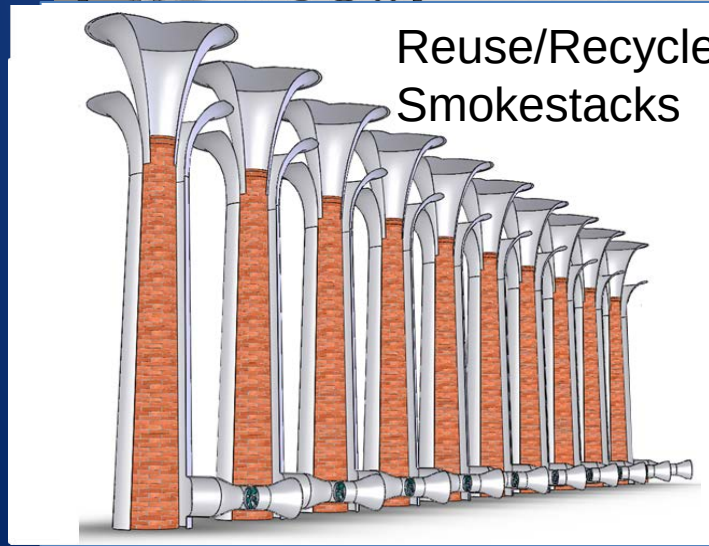
INVELOX - Wind Concentration Systems: Test Configurations

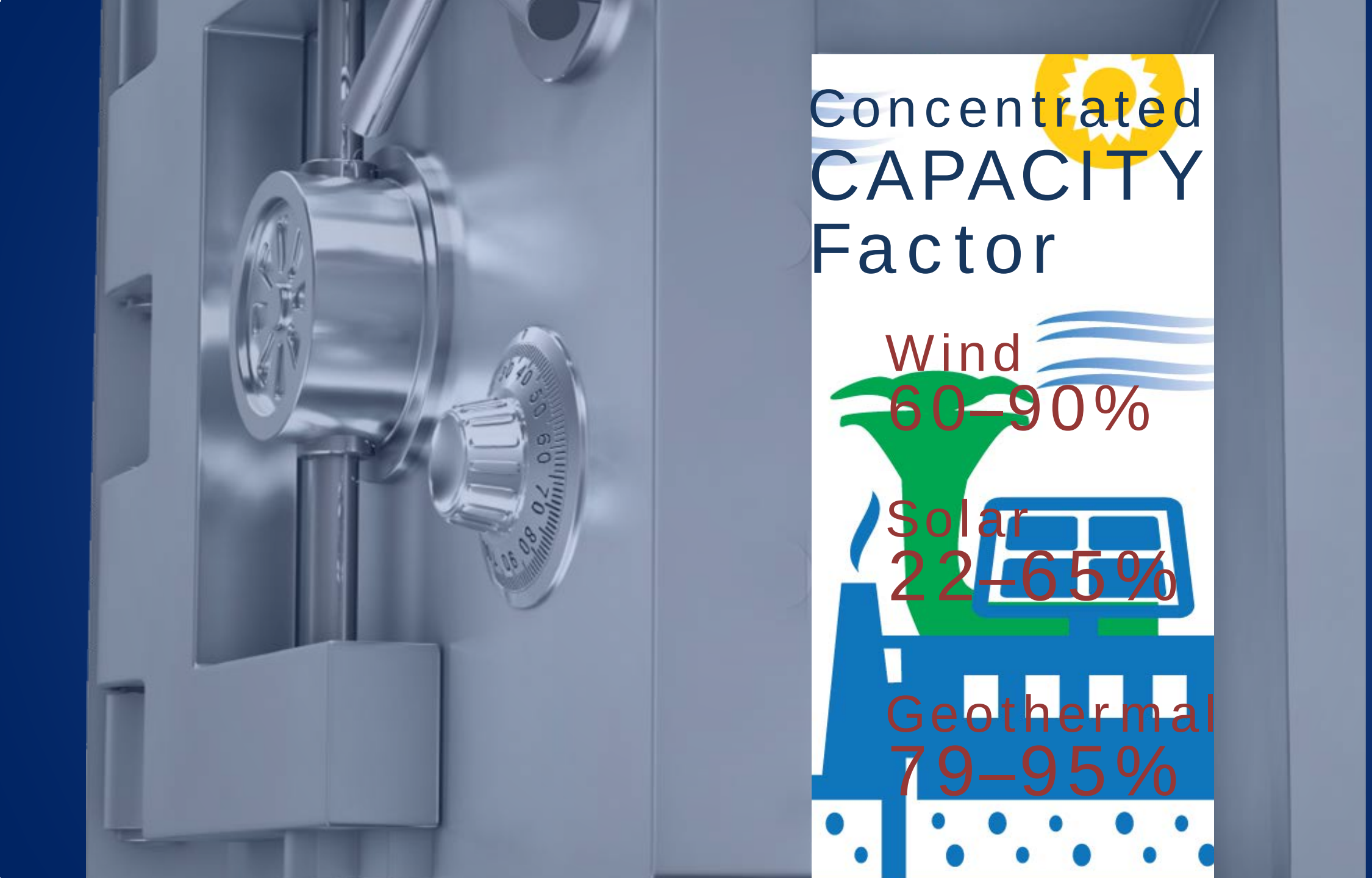
Concentrated Wind Applications

Reuse/Recycle, Retrofit, Building









Concentrated CAPACITY Factor

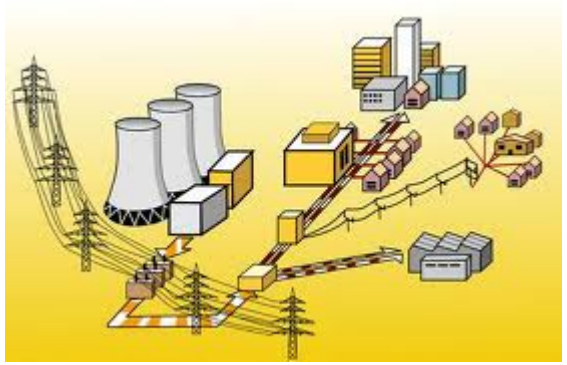
Wind
60–90%

Solar
22–65%

Geothermal
79–95%

Energy and Information

Human Behavior



Information

$$\sum I \Leftrightarrow \sum E$$

Energy

$\sum I$ - **Various Information**

$\sum E$ - **Various Energy**

C.C. Chan 2012

Correlation Between Energy & Information

- Maxwell's Demon, 1867:
  - Information could be thought of as interchangeable with energy;
- J. D. Bekenstein, 1988:
  - Growing trend that the physical world as being made of information;
- C. C. Chan, 2012:

$$\sum I \Leftrightarrow \sum E$$

  - $\sum I$: Various information
  - $\sum E$: Various energy

Energy and Information

- Toyabe et la:

$$\langle \Delta F - W \rangle \leq k_B T I$$

ΔF - Free Energy difference between states

W - Work done on the system

k_B - Boltzmann constant

T - Environment Temperature

- Szilárd:

one bit of information in the system equivalent to energy of $k_B T \ln 2$

Energy and Information

$$\left\{\left\langle \Delta F - W \right\rangle / 1bit\right\} \leq k_B T \ln 2$$

ΔF - *Free Energy difference between states*

W - Work done on the system

k_B - *Boltzmann constant*

T - Environment Temperature

— C.C. Chan 2013 at IASS

Energy & Information

- Not only understand the upper and lower bounds of information,
- But also understand the complex interdependence between the physical limitations of thermodynamic boundaries of energy transfer and the human dimensions of economic, social, and political decisions should be crucially considered.

Energy and Information

- The Boltzmann and Shannon expressions for entropy and information provide boundary values for information in different ways.
- But we should go further to understand the nature of information, such as the real issue of concerns, i.e., the qualitative aspects that address the nature of the information.

Energy & Information

- A very important issue about the management of energy and information, such as the way that information on generation and distribution of energy is managed in a grid plus storage system ,
- this is limited not by the total information content, but largely by the technological options for energy production and the economic and social choices for deployment and distribution, namely the nature of information.

Energy & Information

- Information should be distributed and shared as widely as desired;
- It leads to the realization that the limitation on energy and matter is not simply a matter of producing more energy and deriving information, but on changing the social use of energy and matter;
- Energy efficiency and conservation, creating new business models and opportunities for innovation that is integrated more effectively with the understanding of the needs of the local and global society in a limited resource environment of planet Earth.

Schrödinger equation：

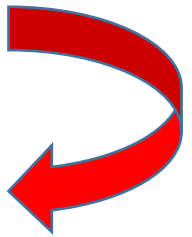
how the quantum state of a physical system changes with time.

Time-dependent Schrödinger equation *(general)*

$$i\hbar\frac{\partial}{\partial t}\Psi = \hat{H}\Psi$$

Ψ：The probability of a Quantum event occurring

One factor that we care(time, cost,… etc)



3D-Time-dependent Schrödinger equation *(single non-relativistic particle)*

$$i\hbar\frac{\partial}{\partial t}\Psi(\mathbf{r},t) = \left[\frac{-\hbar^2}{2\mu}\nabla^2 + V(\mathbf{r},t)\right]\Psi(\mathbf{r},t)$$

Inspiration	激情
Imagination	想像力
Innovation	創新
Integration	集成
Implementation	實現
Investment	投資

Thank you!